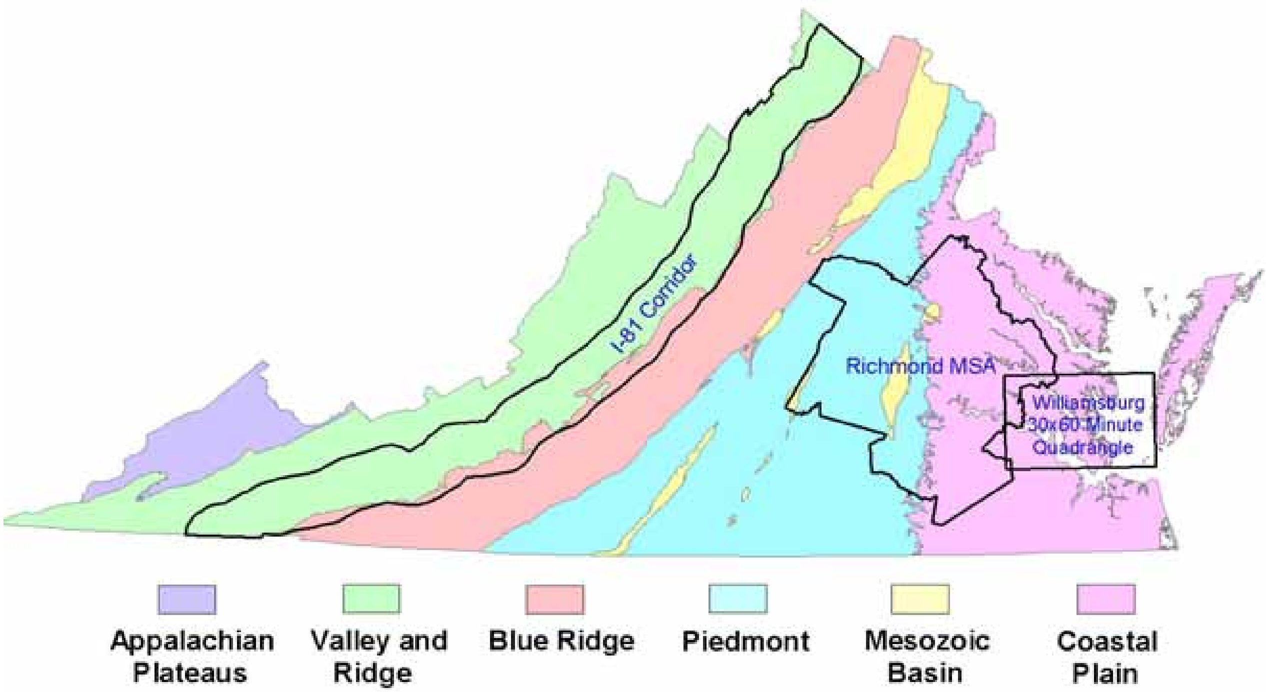
# STATEMAP PROPOSAL - VIRGINIA

*Submitted in response to USGS Program announcement No. 07HQPA0003*




Virginia Department of Mines Minerals and Energy

**October 31, 2006**

# INDEX

## LIST OF FIGURES

## INTRODUCTION

The Virginia Department of Mines, Minerals and Energy, Division of Mineral Resources (DMR) seeks continued funding for geologic mapping along the Interstate 81 corridor, in the Richmond Metropolitan Statistical Area, and in the Williamsburg 30- x 60-minute quadrangle. These long-term projects focus our efforts on three regions of Virginia that are in great need of new and accessible geologic information. The maps we produce will enhance Virginia's ability to develop and conserve natural resources in a safe and environmentally sound manner to support a more productive economy.

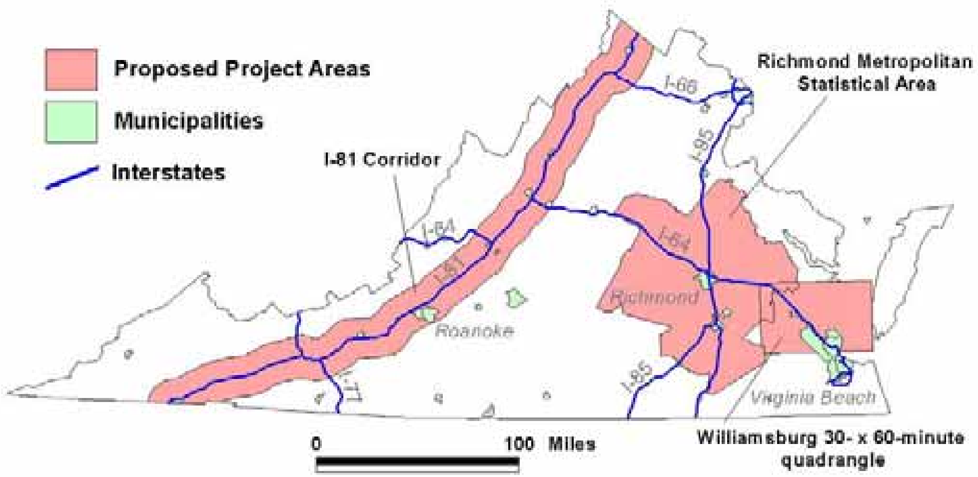



**Figure 1**. Locations of proposed project areas.

**Long Range Plan**

On October 3, 2003, DMR's Geologic Mapping Advisory Committee (GMAC) agreed that geologic mapping is needed in Virginia to locate water resources, develop economic products such as aggregate and sand, identify geologic hazards, protect natural resources, site waste disposal facilities, and develop roads and other infrastructure. The GMAC and DMR staff evaluated areas in Virginia with respect to these needs. At the end of this process, three areas where mapping would provide the greatest benefit were identified: western Virginia, particularly along the I-81 corridor; the Richmond metropolitan area; and along the I-64 corridor between Richmond and Virginia Beach. A long-term mapping strategy has been developed for each area. These strategies consider regional needs, development patterns, mineral resources, the location of existing mapping and staff resources.

DMR recognizes that STATEMAP funding is vital to the completion of long-term mapping projects. We have taken several steps to increase the efficiency of our mapping program and make the very best use of available funds. A significant action has been to schedule the completion of quadrangles in the I-81 Corridor project to take advantage of recently "retired" geologists who have experience in the project areas. These geologists begin work with knowledge of the local stratigraphy and in some cases, existing data. As a result, they are able to complete projects in less time at a reduced cost. We have also minimized travel-related expenses by dividing work on the Richmond MSA project between our Charlottesville and Williamsburg offices and basing a second geologist in Williamsburg. A third strategy is to take advantage of existing subsurface data by converting water well records into a searchable database and obtaining copies of drilling logs generated during environmental and geotechnical investigations in the Richmond area from a local engineering company and state transportation and environmental agencies.

**Virginia Growth**

Virginia is home to more than seven million people. The population of our state is expected to reach almost ten million people by 2030 (U.S. Census Data, 2005). Two thirds of this growth is expected in the Washington D.C., Richmond, and Virginia Beach–Norfolk–Newport News areas (Figure 2). Much of the remaining growth will occur near major highways such as Interstate 81.

Approximately one million people currently live within 10 miles (16.1 km) of I-81 (U.S. Census Data, 2000). Municipal centers in the I-81 corridor include the cities of Winchester, Harrisonburg, Staunton, Lexington, Roanoke, Salem, Wytheville and Bristol. The I-81 corridor's population is expected to grow more than 15 percent by 2030 (Virginia Employment Commission, 2003). Approximately 90 percent of this growth is expected to occur in areas that are currently unincorporated.

Approximately 1.1 million people live in 16 counties designated as the Richmond Metropolitan Statistical Area (U.S. Census Data, 2000). Municipal centers include Richmond, Petersburg, Hopewell, and Colonial Heights. The population of this area is expected to grow approximately 35 percent by 2030 (Virginia Employment Commission, 2003). Almost all of this growth is expected to occur outside of existing city boundaries.

Approximately 470,000 people live in the Williamsburg 30- x 60-minute quadrangle (U.S. Census Data, 2000). Municipal centers include Hampton, Newport News, Poquoson, and Williamsburg. The population of this area is expected to grow approximately 20 percent by 2030 (Virginia Employment Commission, 2003). Much of the growth will occur outside existing city boundaries.

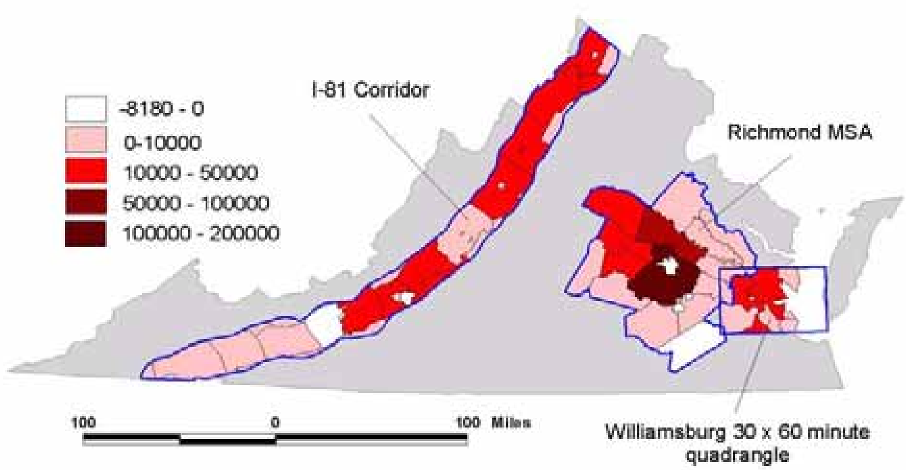



**Figure 2**. Projected population change, by county and municipality, in proposed project areas from 2000 to 2030 (Virginia Employment Commission, 2003).

# INTERSTATE 81 CORRIDOR PROJECT

## Introduction

DMR proposes to continue a concentrated multi-year effort to complete 1:24,000-scale geologic mapping and digital compilation of existing geologic maps along the entire I-81 corridor in Virginia. This portion of the Appalachian Valley is where most of the population lives, works, and travels on a daily basis. It is home to a variety of farms, industries, and commercial enterprises. I-81 is also a nationally significant transportation corridor that connects manufacturers and markets from the southern and northeastern United States.

For the purpose of this study, the I-81 corridor is defined to extend for 10 miles (16.1 km) on either side of the highway. DMR plans to complete 1:24,000-scale geologic mapping of all quadrangles that are wholly or substantially within this corridor. DMR also plans to selectively map quadrangles that are adjacent to the I-81 corridor in areas of current or future growth and in areas where detailed geologic mapping is warranted because of structural or stratigraphic complexity.

Intermediate products for this study will be 1:24,000-scale geologic maps of single or multiple quadrangles, to be published in paper or digital form, and a series of open-file reports on CD that contain files for the current extent of the geologic compilation. The final product will be a 1:24,000-scale digital compilation of the entire corridor.

## Location and Geological Setting

I-81 extends for 325 miles in western Virginia, along the Appalachian Valley. It is the longest interstate in Virginia and has 90 interchanges, including intersections with Interstates I-66, I-64, and I-77. Two proposed Interstates, I-73 and I-74, will also intersect with I-81. Since its completion in the 1960's, I-81 has become the "main street" of western Virginia, serving as a corridor for travel, commerce, and development.

Industries and commercial businesses have located in the I-81 corridor to take advantage of the transportation system. Abundant high quality groundwater supplies in some areas have also attracted industries. Away from municipal centers, agriculture is the dominant industry. In 2002, the 12 counties that I-81 passes through contained approximately 11,850 farms on approximately 1.75 million acres (U.S. Department of Agriculture, 2002). This includes nearly 10,000 livestock operations.

The Appalachian Valley contains headwater portions of five major watersheds. Three of these watersheds are located on the eastern side of the eastern continental divide. The Shenandoah-Potomac and James rivers begin in the north and north-central parts of the Valley. Water from these rivers eventually flows into the Chesapeake Bay. The Roanoke River begins in the central Valley and flows into North Carolina where it enters Albemarle Sound and eventually the Atlantic Ocean. The New and Tennessee rivers, in the southern part of the valley, flow northwest and southwest, respectively, and ultimately enter the Mississippi river system.

The I-81 corridor is predominately underlain by clastic and carbonate sedimentary rocks of the Valley and Ridge geologic province. Metamorphic and igneous rocks of the Blue Ridge geologic province underlie a portion of the eastern edge of the corridor.

Early to late Paleozoic-age limestone, dolostone, sandstone, and shale comprise much of the Valley and Ridge province. These rocks formed from sediments that were deposited in a variety of terrestrial and marine settings. Folding and faulting of these rocks, predominantly during the Alleghanian orogeny, has produced complex geologic structures. Subsequent erosion has resulted in a distinctive topography that is dominated by alternating linear ridges and valleys. The stratigraphic sequence in the Valley and Ridge geologic province was first mapped at a scale of 1:250,000 by Butts (1933 and 1940). Subsequent quadrangle, county and 30- x 60-minute quadrangle mapping in portions of the project area have identified additional evidence for faulting and folding and refined the stratigraphy. It is anticipated that the proposed project will continue to identify map-scale structures, harmonize the portrayal of regional tectonic features, and establish a consistent nomenclature in this portion of western Virginia.

Rocks of the Blue Ridge geologic province are Middle to Late Proterozoic and early Paleozoic in age. The older rocks exist as basement and are unconformably overlain by the younger rocks. Both groups of rocks may overlie a major decollement and sit atop rocks that are thought to be correlative to those exposed in the Appalachian Valley. Contacts between Blue Ridge rocks are commonly sheared, making original relationships difficult to determine.

**Purpose and Justification**

Water resource location, economic product development, geologic hazard identification, natural resource protection and infrastructure development are important issues along the I-81 corridor. Some of these issues are at a critical stage. The need to locate aggregate and identify geologic hazards is very important as Virginia embarks on a two-decade project to expand I-81 and to possibly develop an adjacent long-haul rail system. The need to locate additional water resources continues as development expands. The need to protect natural resources including river systems, forests, groundwater supplies, mineral resources, cave systems, and open space is also increasing in response to development pressures. This project will provide useful information at an appropriate scale to address the issues identified by the GMAC in the following ways:

***Water Resource Location***

Cities and towns in western Virginia obtain their water supplies from groundwater aquifers, surface reservoirs, or a combination of the two. Away from municipal centers, drilled wells are the primary water sources for residents, businesses, and industry. Well yields vary depending upon rock type, location, and depth. In karst and fractured rock aquifers, well yields are unpredictable. Supplies are typically adequate for residential use, but higher yield supplies for industries and municipalities are more difficult to locate. Some surficial deposits in the Appalachian Valley are significant reservoirs for groundwater. Groundwater residing in alluvial fan deposits supplies many businesses in the Valley, including those that require a high quality water source such as Coors Brewery, Merck Chemical, Hershey's Chocolate, and McKee Foods. Detailed geologic mapping will provide useful information to municipalities, businesses, and industries when siting future wells.

***Economic Product Development***

The potential for additional aggregate resources exists along the I-81 corridor. The identification of these resources for quarrying will support continued economic development in the region and provide building material for the expansion of I-81 and new structures. High calcium limestones also exist in the corridor. The demand for these rocks is increasing as clean air regulations come into effect. A wide array of mineral resources have been mined in the past along the I-81 corridor, including crushed and dimension stone, metals, clay, and sand. Detailed geologic mapping will provide useful information to mining companies to further develop the region's mineral resources.

***Geologic Hazard Identification***

Sinkholes are significant hazards along large parts of the I-81 corridor. Between 1971 and 2001, almost 350 sinkholes were discovered in the I-81 right-of-way (Dorman, 2001). In 2001, three successive sinkhole collapses occurred in the median of I-81 within less than a month. Sinkholes are present in other portions of the corridor as well (Hubbard, 1983; Hubbard 1988; Hubbard, 2001). Many sinkhole collapses result from increased water infiltration related to changes in land use.

Landslides/block slides and slope stability are also hazards. These types of problems are common in the northern half of the corridor where the Blue Ridge Mountains meet the Appalachian Valley and in the southern half of the corridor where the hill slopes are steep. Landslides, limited debris flows, and extensive reworking of alluvial boulder deposits can occur during a period of heavy rainfall, like the one experienced with Hurricane Isabel in 2003 and Hurricane Ivan in 2004. Even on moderate slopes, some rock types and geologic structures create stability problems for structures and roads. Areas underlain by shale and some limestone formations are particularly susceptible to erosion, acidity, or foundation shift because of shrinking and swelling of residual clay soil.

***Natural Resource Protection***

Development pressures within the I-81 corridor are resulting in changes in land use. Open space is being converted to industrial, commercial, and residential use. These changes are certain to have both positive and negative effects on the region's natural resources. In many cases, the geology can play an important role in the nature and extent of these impacts. Detailed geologic maps will provide useful information to land use planners, natural resource caretakers, and environmental consultants who work in the corridor.

Water contamination is a significant problem in many parts of the I-81 corridor. Water quality in the region is impacted by a number of pollution sources, including agricultural run off, failing septic systems, and excessive sedimentation (Virginia Department of Environmental Quality, 2003). Many crops are fertilized with animal waste from concentrated feeding operations such as dairies and poultry farms. Nitrogen loads in the Shenandoah-Potomac basin increased 11 percent between 1985 and 2000, to an estimated total of 12,000,000 pounds (Virginia Department of Environmental Quality, 2003). Nutrients are a major water quality problem in the Chesapeake Bay, which is the ultimate receiver of water from the Shenandoah River (Environmental Protection Agency, 2002). Approximately 52 percent of monitored streams and rivers in the Shenandoah-Potomac basin are threatened, not fully supporting, or not supporting their designated uses (Virginia Department of Environmental Quality, 2003).

***Roads and other Infrastructure Development***

A statewide expansion of I-81 is in the planning stages and will occur over the next two decades. This expansion project will include the widening of the interstate, and possibly the installation of rail along the corridor and other improvements. Additional projects include the construction of I-73 and I-74 in the vicinity of Roanoke. Commercial, industrial, and residential development and associated utilities will likely follow road construction and expansion projects. Detailed geologic maps will provide useful information to the Virginia Department of Transportation, municipal and private utilities, and private and public land developers.

**Strategy for Performing Geologic Mapping**

Most 7.5-minute quadrangles in the I-81 corridor have geologic coverage that falls into one of the following categories: published mapping at 1:24,000 scale; unpublished or published mapping at a scale between 1:50,000 and 1:100,000; unpublished or published mapping at a scale of 1:125,000 or 1:250,000; and no mapping at a scale of less than 1:250,000 (Figure 3). Our strategy is to compile existing blocks of published 1:24,000-scale maps and bring the level of mapping in other quadrangles up to 1:24,000-scale quality. Geologic and digital compilation will be continually expanded as new quadrangles are mapped.

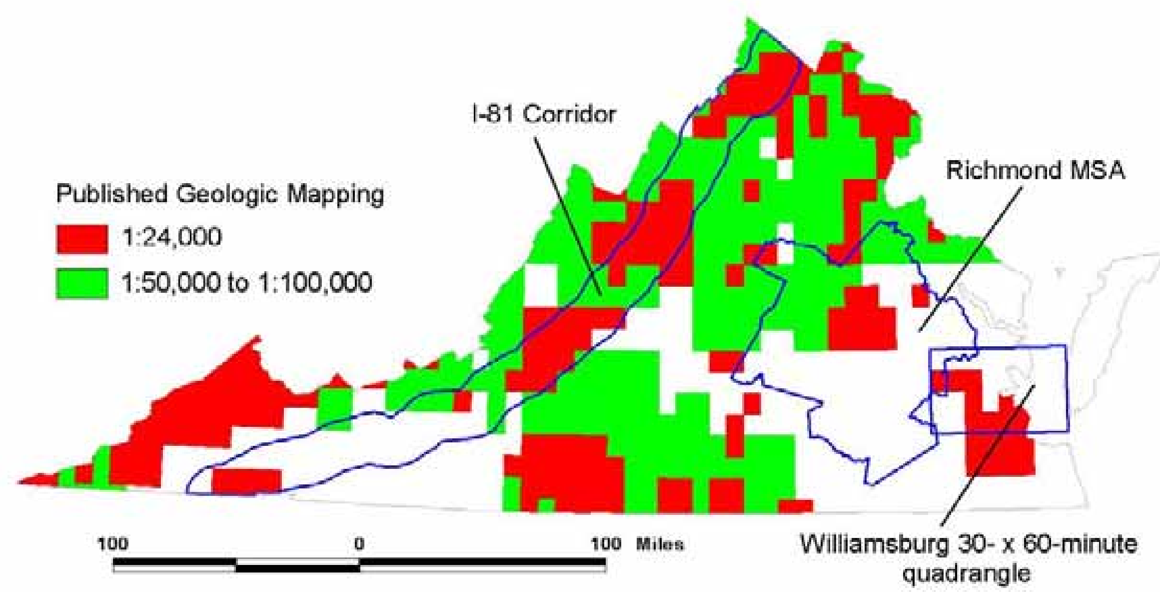



**Figure 3.** Published geologic map coverage in Virginia. Other areas rely upon 1:125,000- and 1:250,000-scale maps of the Coastal Plain and Appalachian Valley or the 1:500,000-scale state map.

Quadrangles to be mapped early in the project are those:

- where new geologic mapping is needed to address an important environmental, development or natural resource issue;
- adjacent to previously compiled geologic maps;
- where existing geologic mapping is nearly 1:24,000 quality;
- where existing geologic mapping has been completed at 1:100,000-scale.

This project requires mapping approximately 70 quadrangles. Half of these quadrangles have not previously been mapped at a scale of less than 1:250,000. The final product will involve digital compilation of these maps and approximately 60 additional quadrangles. It is anticipated that the I-81 corridor geologic mapping project could be completed in approximately 13 years with continued funding. For 2007-2008, the project will consist of the two separate sub-projects outlined below:

**1. Geologic Mapping**

1:24,000-scale mapping of the Atkins (½), Broadford (½), Elkton West (½), Elliston, Goshen, Montebello (½), and Stanley (½) quadrangles is proposed (Figure 4). All of the quadrangles are entirely or substantially within the I-81 corridor.

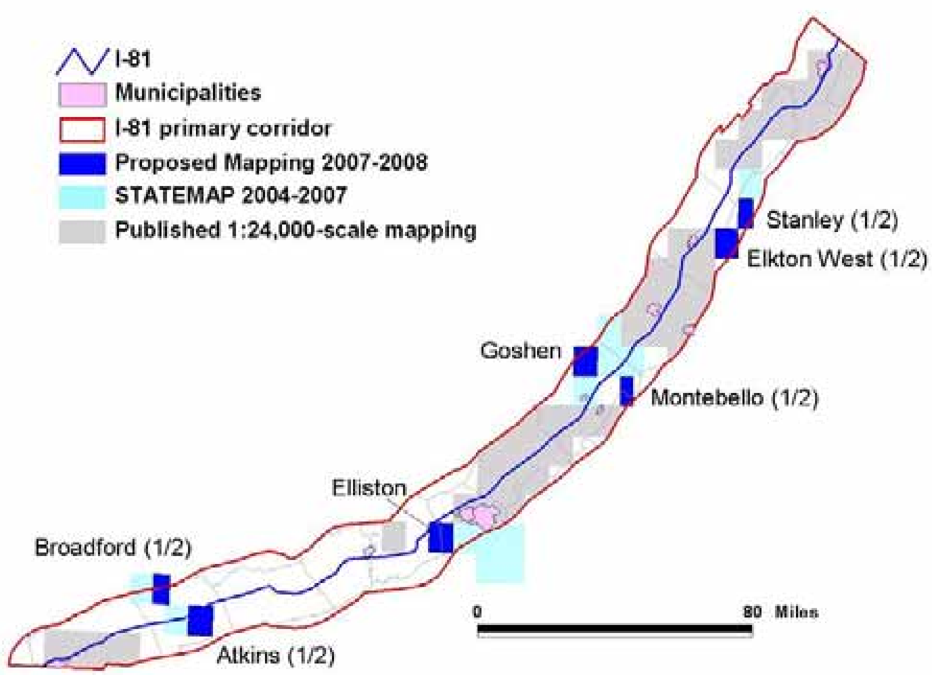



**Figure 4.** 7.5-minute quadrangles proposed for new geologic mapping within the I-81 Corridor project.

Bill Whitlock will be mapping the Atkins quadrangle. Fred Webb and Loren Raymond will be mapping the Broadford quadrangle. Matt Heller will be mapping the Elkton West quadrangle. Bill Henika will be mapping the Elliston quadrangle. Gerry Wilkes will be mapping the Goshen quadrangle. Mark Carter and Matt Heller will be mapping the Montebello quadrangle. Steve Whitmeyer will be mapping the Stanley quadrangle.

As part of the mapping program, samples that are representative of significant map units will be collected. One portion of these samples will be submitted for whole rock analysis. A second portion will be used to make thin sections. A third portion will be placed into our rock repository. Whole rock analyses will include major, minor, trace and rare earth elements. The analytical results will be used to correlate rock types and identify potential mineral resources, including high calcium limestone. The results will be compiled into a database that is available to the public. One anticipated use is to identify the background concentrations of metals such as arsenic, barium, cadmium, chromium, lead, and mercury that are routinely detected in soil and groundwater during environmental investigations. Physical testing of potential aggregate resources may also be completed.

## 2. Geologic Compilation

This project will build upon our 2003 through 2007 STATEMAP geologic compilation, consisting of 25 7.5-minute quadrangles. This year we will add the following seven quadrangles: Augusta Springs, Bent Mountain, Churchville, Conicville, Edinburg, Redwood, and Saltville (Figure 5). With the exception of Redwood and Saltville, all of the quadrangles are wholly or substantially within the I-81 Corridor. Saltville is partly in the corridor and has significant mineral resources. Redwood is situated along the proposed route for Interstate 73. Both were recently mapped for the I-81 Corridor project.

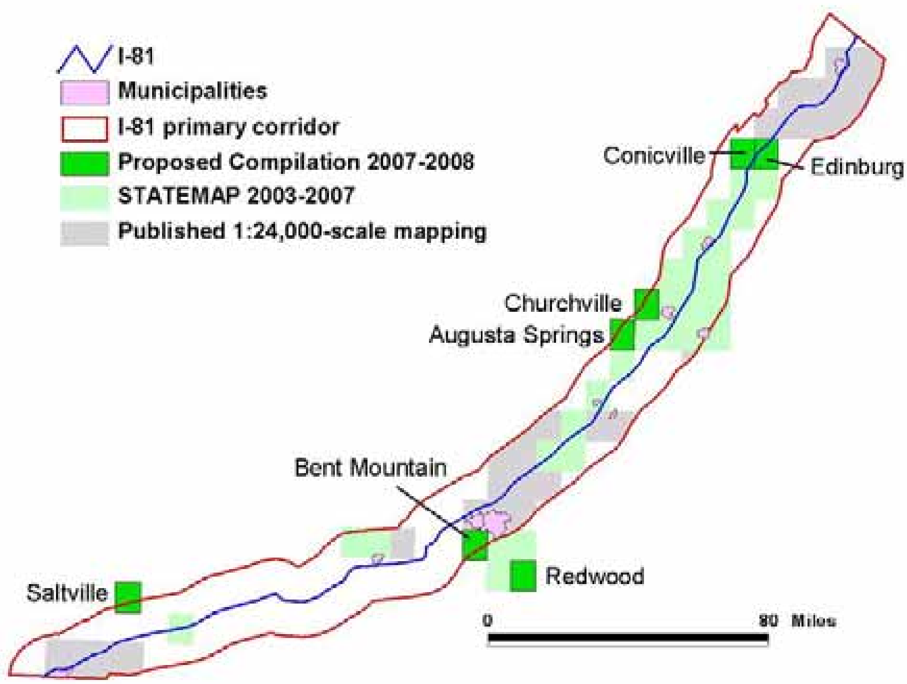



**Figure 5.** 7.5-minute quadrangles proposed for digital geologic compilation within the I-81 Corridor project.

The Churchville, Conicville and Edinburg quadrangles were published more than 30 years ago (Rader, 1967; Young and Rader, 1974) and require field checking to examine new exposures, improve data density, and resolve map boundary "faults" and structural or stratigraphic inconsistencies. Geologic mapping of the Augusta Springs, Bent Mountain, Redwood, and Saltville quadrangles has been completed during the past three years. As a result, significant field checking of these quadrangles will not be required.

The GIS files for these quadrangles will be created by digitizing or importing and editing the geologic features from the original maps as points, lines and polygons, attributing these features and incorporating any changes and new data resulting from field checking. Metadata and printable maps will be created based on the updated geologic information.

**Preliminary Results and Previous Work**

New geologic mapping of eleven quadrangles (Boones Mill, Brownsburg, Elkton West (½), Garden City, Grottoes (½, surficial), Hardy, Hamburg, Lexington, Marion, Redwood, Saltville (½), and Vesuvius has been completed for the I-81 Corridor project between 2004 and 2006. Our current STATEMAP project involves mapping the Atkins (½), Augusta Springs, Bent Mountain, and Saltville (½) quadrangles.

Our 2003-2006 digital compilation projects included a total of eighteen 1:24,000 geologic maps along the Interstate 81 corridor between New Market and Greenville and south of Lexington (Figure 5). Newly acquired and original field data have also been incorporated into the compilation. Approximately eighteen months of fieldwork have been completed to resolve map boundary discrepancies, structural complexities, and to provide new data upon which to base cross sections. Our current STATEMAP digital compilation for the I-81 Corridor project includes the revision and compilation of the Boones Mill, Brownsburg, Garden City, Hardy, Lexington, Marion, Radford North, and Staffordsville quadrangles (Figure 5).

New mapping and targeted remapping for this project is helping to refine the stratigraphy and structure of the Valley and Ridge province and adjacent Blue Ridge and Inner Piedmont. Field Checking in the Martinsburg formation in the Fort Defiance, Staunton, Stuarts Draft, and Waynesboro West quadrangles in 2003-2004 provided evidence for multiple periods of deformation within the Martinsburg formation (Duncan and Others, 2004). Field checking along the Blue Ridge front in the Crimora, Waynesboro East and Waynesboro West quadrangles in 2004-2005, supported by seismic profiles made available since the original maps were published, provided evidence for the existence of a "Blue Ridge" fault separating Chilhowie Group rocks from those of the Rome Formation (Williams and others, 2006). This is a change from the original maps, which show an intact stratigraphic sequence, and is consistent with recent interpretations further south in Virginia and North Carolina. Mapping in the Boones Mill, Garden City and Hardy quadrangles in 2004-2005, supported by geochemical analyses, has helped to establish genetic relationships among deformed plutonic and volcanic rocks of the Blue Ridge and inner Piedmont (Henika, 2006). Ongoing mapping in the Elkton West quadrangle confirms the presence of a significant backthrust within the Massanutten Synclinorium. This structure was previously suggested by 1:100,000-scale mapping (Rader and Gathright, 2001a and 2001b).

*Previous Work*

Existing data are available for most of the new mapping projects. Half of the Atkins and Elkton West quadrangles have been mapped through the STATEMAP program. A portion of the Atkins quadrangle was also mapped previously at 1:31,800- and 1:62,500-scale (Miller and Wilpolt, 1944; Currier, 1935). Regional and county maps are available for the Elkton West and Stanley quadrangles (Brent, 1960; Allen, 1967; Rader and Gathright, 2001a and 2001b), A 1:24,000-scale map of a portion of the Elkton West and Stanley quadrangles is also available (King, 1950). The Elliston quadrangle has previously been mapped at 1:100,000-scale (DMR, Unpublished data). The Goshen quadrangle has been mapped at 1:50,000-Scale (Wilkes, in preparation). The Montebello quadrangle has been mapped at 1:62,500-scale (Werner, 1966). A portion of the Montebello quadrangle in the Irish Creek tin district has been the focus of detailed mapping and investigation (e.g. Koschmann and others, 1942; Hudson, 1981). A portion of the Broadford quadrangle was mapped at 1:12,000-Scale by Ross (1965).

Existing data are also available for the digital compilation project. The Churchville quadrangle has been published at 1:24,000-scale (Kozak, 1970). The Conicville and Edinburg quadrangles have also been published at 1:24,000-scale (Young and Rader, 1967). The Bent Mountain, Redwood and Saltville quadrangles were mapped at 1:24,000-scale during our 2005-2007 STATEMAP grants.

**Deliverable Maps**

The deliverables for this project will be:

1. Geologic map and cross-section of half of the Atkins quadrangle;
2. Geologic map and cross-section of half of the Broadford quadrangle;
3. Geologic map and cross-section of half of the Elkton West quadrangle;
4. Geologic map and cross-section of the Elliston quadrangle;
5. Geologic map and cross-section of the Goshen quadrangle;
6. Geologic map and cross-section of half of the Montebello quadrangle;
7. Digitally compiled geology as GIS files of the following seven 1:24,000 quads: Augusta Springs, Bent Mountain, Churchville, Conicville, Edinburg, Redwood, and Saltville (paper copies of each quadrangle that is part of the compilation will also be provided).

## RICHMOND METROPOLITAN STATISTICAL AREA PROJECT

### Introduction

DMR proposes to continue a multi-year effort to complete 1:24,000-scale geologic mapping and digital compilation of existing geologic maps in a portion of a 16-county area that has been designated by the U.S. Office of Management and Budget as the Richmond Metropolitan Statistical Area (MSA). According to the U.S. Census Bureau website, "the general concept of a metropolitan or micropolitan statistical area is that of a core area containing a substantial population nucleus, together with adjacent communities having a high degree of social and economic integration with that core." DMR and the GMAC have targeted the Richmond MSA for investigation because it is a recognized jurisdiction that encompasses the area of future growth around Richmond.

The Richmond MSA straddles the Piedmont and Coastal Plain provinces. It is situated at the intersection of three major interstates, I-95, I-64, and I-85 (Figure 1). This area is home to approximately one in seven of Virginia's citizens, and houses nearly every type of business and industry. Agriculture is a stable to growing part of the area's economy, with approximately 4,300 farms on nearly one million acres (U.S. Department of Agriculture, 1997 and 2002). This area encompasses all or a portion of six regional planning districts.

DMR has ranked the 95 unpublished 7.5-minute quadrangles that are substantially within the Richmond MSA either a low or high priority. This ranking is based upon societal needs identified by the planning districts or other government agencies and the potential for mineral resources or geologic hazards. Quadrangles that are assigned a high priority ranking meet one or more of the following criteria:

- Significant change in land use anticipated;
- High potential for mineral resources;
- Known geologic hazards exist;
- Population center or highly developed area;
- Along an Interstate.

The goal of this project is to complete 1:24,000-scale geologic mapping of all quadrangles in the MSA that are identified as high priority (Figure 6). An ultimate goal is to use this data in combination with existing data on the low priority quadrangles to create a 1:100,000-scale geologic map of the entire MSA. Intermediate products for this study will be 1:24,000-scale geologic maps of single or multiple quadrangles, to be published in paper or digital form, and a series of open-file reports on CD that contain files for the current extent of the geologic compilation.

### Location and Geological Setting

The Richmond MSA encompasses 16 counties in the Piedmont and Coastal Plain of Southeast Virginia. The cities of Richmond, Petersburg, Colonial Heights, and Hopewell are located along interstates I-95, I-64, and I-85. Several major U.S. Highways connect these cities with smaller communities both inside and outside of the MSA. The region contains significant portions of three river basins. From north to south they are the York, James, and Chowan. The lower portions of the York and James rivers flow through the area and into the Chesapeake Bay. Several smaller rivers form the headwaters of the Chowan River, which begins in North Carolina and becomes part of the Albemarle / Pamlico-River Basin. The Chesapeake Bay and the lower reaches of the Albemarle / Pamlico-River Basin represent the largest and second largest estuarine systems in the United States, respectively.

The western half of the Richmond MSA is located in the Piedmont physiographic province. Crystalline rocks in the Piedmont portion of the MSA may be assigned to three separate terranes. From west to east they are the Chopawamsic terrane, the Goochland terrane, and the Southeastern Piedmont terrane. The Chopawamsic terrane contains metavolcanic, metaplutonic and metasedimentary rocks of similar age that are believed to have formed in an early to middle Paleozoic-age volcanic arc (Coler and others, 2000). The Goochland terrane is composed of multiply deformed igneous rocks and metamorphic rocks of uncertain affinity. At least a portion of the Goochland terrane is Mesoproterozoic in age. The Goochland terrane is separated from the Chopawamsic terrane by the Spotsylvania shear zone and from the Southeastern Piedmont terrane by the Hylas shear zone (Spears and others, 2004). The Southeastern Piedmont terrane contains a variety of metamorphic rocks, some of which appear to have volcanic protoliths. The late Paleozoic-age Petersburg Granite intrudes a substantial portion of the Southeastern Piedmont terrane in the project area. Another portion is unconformably overlain by Mesozoic-age sedimentary rocks of the Farmville, Richmond, and Taylorsville basins, which were deposited in a series of half-grabens. All three of these basins have had historic coal production and oil and gas exploration.

Much of the eastern half of the Richmond MSA lies within the Fall Zone. In this complex zone, Coastal Plain sediments overlie rocks of the eastern Piedmont. Both sediment and rocks are exposed and mappable. The age of sediments ranges from Cretaceous through Pleistocene. Estuarine and fluvial sediments of Miocene-Pliocene age are found capping the higher elevations and become thinner to the west, extending at least 20 miles west of the Fall Line (boundary at land surface between the Piedmont and Coastal Plain provinces) at Richmond.

## Purpose and Justification

### *Water Resource Location*

The City of Richmond and nearby counties of Henrico and Chesterfield in the Richmond MSA obtain their water supplies from surface sources, including the James River. Most other public and private water supplies in the MSA are groundwater-based. Well yields and water quality vary depending upon rock type, location, and depth. Shallow wells in the Coastal Plain may be vulnerable to surface contamination. In fractured crystalline rock aquifers, well yields are unpredictable, although supplies are typically adequate for residential use. Higher yield supplies for industries and municipalities are more difficult to locate. Detailed geologic mapping will provide useful information to municipalities, businesses, and industries when siting reservoirs and wells.

***Economic Product Development***

The Richmond Metropolitan Statistical Area (MSA) currently contains over 50 active mine and quarry operations, which produce economically significant quantities of crushed stone, clay, sand, gravel, and several industrial minerals. The crushed stone, clay, sand, and gravel resources provide local sources for high-demand construction materials. Industrial minerals such as aplite, vermiculite, and fuller's earth are exported from the Richmond area, providing business income and local jobs. Titanium and zircon are currently being produced from a nationally significant heavy mineral mine in the southern part of the MSA.

Past mineral production in the Richmond MSA includes many commodities not currently being produced, but which may have potential for redevelopment in the future. Coal was produced locally for over two hundred years; while it's not likely that coal mining will return to Richmond, deep coal deposits have been explored in recent years for coal bed methane. Gold, sulfide minerals, and mica were produced in the past and may still be present in significant quantities. Improvements in technology or changes in demand may make some of these commodities economically viable in the future. Detailed geologic maps will be critical for the evaluation and development of these resources.

***Geologic Hazard Identification***

Known geologic hazards in the Richmond MSA include acidic soils, shrink-swell soils, subsidence in the vicinity of abandoned underground mines, flooding, slope stability, and unsafe levels of radon and other potentially hazardous naturally occurring elements in soil and groundwater.

Surface collapses in the vicinity of historic coal mines in the Richmond basin have been a significant problem in recent years, because of residential and commercial development in former coal mining areas. Since most of these mines were abandoned in the 1800's, their exact locations and extents are often unknown. Acidic soils associated with the Eastover Formation are widespread in the eastern portion of the Richmond MSA. Water discharging from these soils can have a pH of 2 or 3. This can contribute to habitat degradation in streams and the premature failure of concrete and metal structures. The remnants of tropical depression Gaston in 2004 caused severe flooding and numerous landslides in downtown Richmond and vicinity. Understanding the geology of this area will help reconstruction and prevent future landslides.

***Natural Resource Protection***

Developmental pressures within the Richmond MSA are causing changes in land use. During development, open space is converted to industrial, commercial, and residential use. These changes are certain to have both positive and negative effects on the region's natural resources. In many cases, the geology can play an important role in the nature and extent of these impacts. Detailed geologic maps will provide useful information to land use planners, natural resource caretakers, and environmental consultants who work in the MSA. The Petersburg and Richmond National Battlefield sites are located in the Richmond MSA. The National Park Service has expressed interest in geologic mapping of these properties and surrounding areas to support park management.

Water contamination is a significant problem in many parts of Richmond MSA. Water quality in the region is impacted by a number of pollution sources, including contaminated water run off and excessive sedimentation (Virginia Department of

Environmental Quality, 2003). Non-point and point source pollution in developing areas also contributes fertilizers, pesticides, petroleum products, solvents, and other chemicals to streams and aquifers. Development often results in greater areas of impervious surfaces, resulting in increased surface overland flow into streams. 62 percent and 51 percent of monitored streams and rivers in the York and James River Basins, respectively, are threatened, not fully supporting, or not supporting aquatic life (Virginia Department of Environmental Quality, 2003). These rivers affect water quality in the Chesapeake Bay. Monitoring suggests that 93 percent of the Chesapeake Bay is threatened, not fully supporting, or not supporting aquatic life.

***Waste Disposal Facility Siting***

As development in the region continues, additional solid and liquid waste disposal facilities will need to be constructed. These include municipal landfills, wastewater treatment plants, and land application sites. Detailed geologic maps will provide useful information to the decision makers who site and regulate these facilities.

***Roads and Infrastructure Development***

Several major highway construction projects are underway or are being planned for the future, including the expansion and realignment of U.S. Highway 460 and the widening of I-64 east of Richmond. Detailed geologic maps will provide useful information to the Virginia Department of Transportation, municipal and private utilities, and private and public land developers.

## Strategy for Performing Geologic Mapping

Most 7.5-minute quadrangles in the Richmond MSA have geologic coverage that falls into one of three categories: published mapping at 1:24,000 scale; unpublished or published mapping at a scale between 1:24,000 and 1:250,000; and no mapping at a scale of less than 1:250,000 (Figure 3). Our strategy is to compile existing blocks of published 1:24,000-scale maps and bring the level of mapping in high priority quadrangles up to 1:24,000 quality. Geologic compilation will be continually expanded as new quadrangles are mapped.

Quadrangles to be mapped early in the project are those:

- where new geologic mapping is needed to address an important environmental, development or natural resource issue;
- adjacent to previously compiled geologic maps;
- where existing geologic mapping is nearly 1:24,000 quality.

This project will require mapping approximately 45 quadrangles (Figure 6). Unpublished data exist for many of these quadrangles, but only seven are covered by published mapping at a scale of greater than 1:250,000. The final product will involve the compilation of these maps and 13 previously published quadrangles. It is anticipated that the Richmond MSA geologic mapping project could be completed in approximately 13 years with adequate staff and funding. For 2007-2008, we propose the project outlined below:

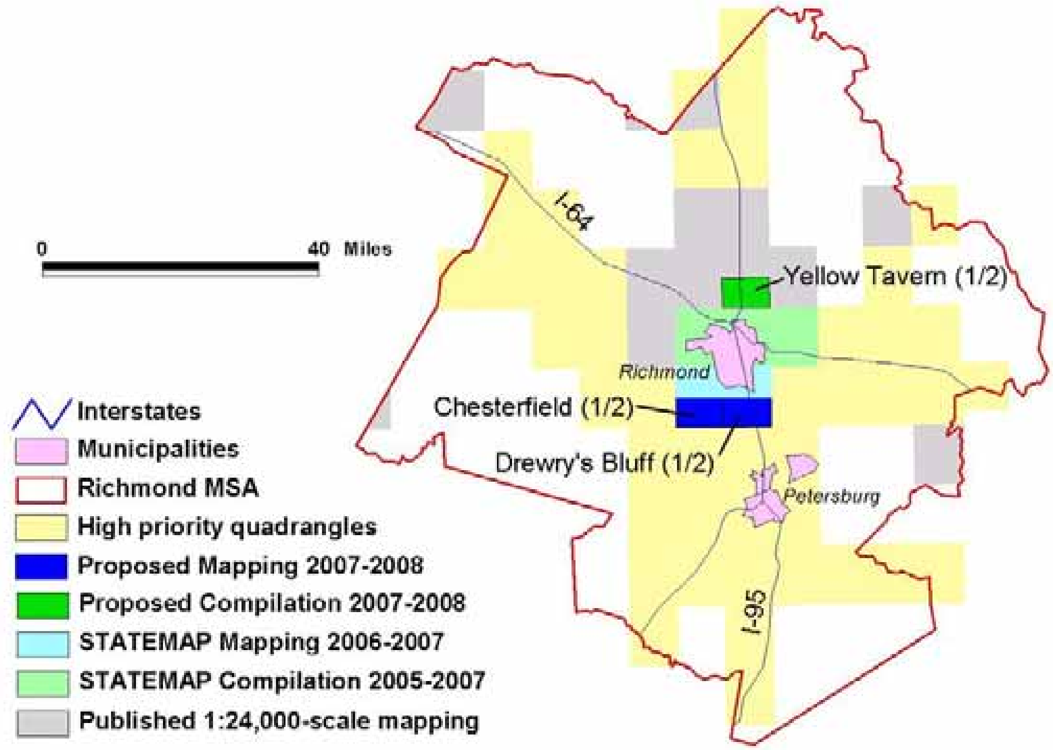



**Figure 6.** 7.5-minute quadrangles proposed for new mapping and compilation within the Richmond MSA project area.

## 1. Geologic Mapping

1:24,000-scale mapping of the Chesterfield (½) and Drewry's Bluff (½) quadrangles is proposed (Figure 6). These quadrangles are located immediately south of the City of Richmond. They are ranked by DMR as high priority because they contain highly developed and developing areas. The Drewry's Bluff quadrangle encompasses a portion of I-95.

As part of the mapping program, samples that are typical of significant map units will be collected. A portion of these samples will be submitted for whole rock analysis. A second portion of consolidated rocks will be used to make thin sections. A third portion of consolidated rocks will be placed into our rock repository. Whole rock analyses will include major, minor, trace, and rare earth elements. The analytical results will be used to correlate rock types and identify potential mineral resources. The results will be compiled into a database that is available to the public. One anticipated use is to identify the background concentrations of metals such as arsenic, barium, cadmium, chromium, lead, and mercury that are routinely detected in soil and groundwater during environmental investigations.

Mark Carter will be mapping the Chesterfield quadrangle. Rick Berquist and Amy Bondurant will be mapping the Drewry's Bluff quadrangle.

## 2. Geologic Compilation

This project will build upon our 2005-2007 STATEMAP geologic compilation, consisting of the Richmond, Bon Air, and Seven Pines 7.5-minute quadrangles. This year we propose geologic compilation and targeted remapping of the southern half of the Yellow Tavern quadrangle (Figure 6). This quadrangle is located in a highly developed and rapidly developing area near the intersection of Interstates 95 and 64 and spans the boundary between the Piedmont and Coastal Plain provinces. Acid drainage, flooding potential, slope stability and radon are known or potential geologic hazards in the quadrangle. Mark Carter, Amy Bondurant, and Rick Berquist will work on this project.

The Yellow Tavern quadrangle was published in 1974. Significant development has occurred in this area during the intervening time, creating new exposures. This project will involve significant field checking to examine existing and new exposures. In areas where crystalline rocks are exposed, an emphasis will be placed on measuring the orientations of joints and filled fractures, which are lacking on the original maps. Targeted remapping of problem areas, the addition of structural data and the updating of stratigraphic nomenclature will also be performed. The GIS files for these quadrangles will be created by digitizing and editing points, lines and polygons from the original maps, attributing these features and incorporating changes and new data resulting from field checking. Printable maps showing the updated geology and metadata will be created.

## Preliminary Results and Previous Work

### *Preliminary Results*

We are in our second year of compiling new and existing geologic maps in the Richmond MSA. In our first year, we significantly updated and re-mapped previously published geologic maps of the Richmond and portions of Bon Air and Seven Pines 7.5-minute quadrangles. This year, we are completing the Bon Air and Seven Pines quadrangles, and extending new mapping south and westward along US 360 and I-95 on the Chesterfield and Drewrys Bluff 7.5-minute quadrangles. New mapping in these areas has significantly increased our understanding of inner Coastal Plain and Southeastern Piedmont stratigraphy, structure, and geomorphic evolution, and highlighted several geologic issues of societal importance:

*Petersburg Granite and potential Radon Gas emissions*

Previous geologic maps (Daniels and others, 1974; Goodwin, 1980, 1981) grossly subdivided the Mississippian Petersburg Granite into two units in this area: uniform textured granite, and porphyritic granodiorite. We are now accurately delineating three phases of Petersburg Granite intrusion: an early phase consisting of well-foliated to layered granite gneiss, a fine- to coarse-grained subidiomorphic middle phase, and a late phase of coarse porphyritic granite in map-scale screens and discrete zones. Within these phases, we are also recognizing map-scale xenoliths of biotite gneiss and schist, and mafic and altered ultramafic rocks. A research goal in the coming year is to gather existing radon data in the map area and look for correlations with the three granite phases; if significant associations are found, our new maps may be useful for outlining areas greater potential for radon problems.

*Economic Earth Material and Mineral Resources*

Definition and nomenclature of Coastal Plain stratigraphy has significantly increased in the years since publication of the original quadrangles in this area. For instance, we now recognize that Pliocene Yorktown Formation and Pliocene-Pleistocene Bacons Castle

Formation lithologies extend westward into the inner Coastal Plain (e.g., Mixon and others, 1989). Our new mapping demonstrates that sand and gravel of the Bacons Castle Formation underlies vast areas of the Richmond and Seven Pines quadrangles between the Chickahominy and James Rivers, and is a virtually untouched source of aggregate in this increasingly urbanized region. Additionally, we have recognized internal stratigraphy within the near-shore facies of the Yorktown Formation in the Richmond area. South of Petersburg, similar Yorktown lithofacies hold the largest deposits of heavy minerals in the eastern US. Continued detailed mapping in the Richmond area may reveal additional reserves.

*Relationship between surfical deposits and Cenozoic faults, and Paleo-seismicity*

West of Richmond on the Bon Air quadrangle, new mapping has revealed a heretofore-unrecognized surficial unit consisting of rounded pebbles, cobbles, and boulders within a matrix of quartz and feldspar clayey sand (Carter and others, 2006). Clasts are unsorted, matrix supported, and consist of quartz, quartzite, and granite. Mapping suggests that the unit represents Tertiary to Quaternary colluvium, shed down-slope from Miocene upland gravel terraces. Surprisingly, our new work also suggests a relationship between the colluvium and silicified breccia zones in the underlying granite. Although traditional interpretation dictates silicified breccias are Mesozoic in age, several key exposures hint that the colluvium is offset by, or deposited down-dip of apparently reactivated breccia zones. Likewise, reactivated silicified breccias may have also controlled deposition of a heretofore-unmapped fossiliferous marine clayey to silty fine sand unit that locally underlies Miocene upland gravel terraces south of the James River. This unit may be equivalent to the Miocene Eastover Formation that crops out to the east on the Richmond and Seven Pines quadrangles; if so, there is an approximately 150 ft elevation difference between the outcrop belts. Continued mapping (coupled with paleontologic, geochemical, and petrographic analyses) should a) further constrain the age of the colluvial deposits and the marine clayey sand unit beneath the upland gravels, and b) determine the role of Cenozoic faulting and paleoseismicity recurrence.

### *Previous Work*

The Yellow Tavern map has been published at 1:24,000-scale (Daniels and Onuschak, 1974). Dischinger (1987) mapped a very small portion of the Drewry's Bluff quadrangle. In addition, DMR has field data collected on all of the quadrangles in this project area that were collected for the completion of the 1:250,000-scale map of the Virginia's Coastal Plain (Mixon and others, 1989) or the 1:500,000-scale Geologic Map of Virginia (VDMR, 1993)

### Deliverable Maps

The deliverables for this project will be:

1. Geologic map and cross-section of the southern half of the Chesterfield quadrangle;
2. Geologic map and cross-section of the southern half of the Drewry's Bluff quadrangle;
3. Digitally compiled geology as GIS files of the southern half of the Yellow Tavern 1:24,000 quadrangle (A paper copy of the quadrangle will also be provided).

## WILLIAMSBURG 30 x 60-MINUTE QUADRANGLE PROJECT

### Introduction

DMR proposes to continue its effort to complete geologic mapping and digital compilation in the Williamsburg 30- x 60-minute quadrangle (Figure 1). There are approximately 4.5 7.5-minute quadrangles (and small parts of two quadrangles on the Eastern Shore) that have not been mapped in detail (Figure 7). Six 7.5-minute quadrangles in the Williamsburg sheet were mapped between 2000 and 2006 with STATEMAP funding. Mapping the Walkers 7.5-minute quadrangle will complete the northern half of the 30- x 60-minute quadrangle. The Walkers quadrangle is along I-64, and is experiencing rapid development.

DMR relies heavily upon the use of its auger drilling rig for geologic mapping in the coastal plain. Although exposed map units may appear simplistic in some coastal areas, a refined delineation of the subsurface framework is critical to understanding the shallow aquifers and identification of sand/aggregate resources. STATEMAP funding will support assistance with mapping, drilling, sample analysis, and GIS compilation.

The final product for this project will be a 1:100,000-scale digital compilation of the entire Williamsburg sheet. We anticipate that it will take approximately two years to finish the project.

### Location and Geological Setting

The Williamsburg 30- x 60-minute quadrangle lies completely within the tidewater region of Virginia (Figure 1). I-64 passes diagonally through the map area and is the major corridor for travel, commerce, and development between Richmond and the Virginia Beach–Norfolk–Newport News area. The trace of the interstate here defines the southern part of the “Golden Crescent” (an area of high population and development) that continues from Richmond to Washington DC. Other prominent geographic features are the York and James rivers, two major estuaries that are tributaries to the Chesapeake Bay. The eastern third of the Williamsburg sheet encompasses both shorelines of the lower Chesapeake Bay.

The region is home to major tourist attractions such as Colonial Williamsburg, Busch Gardens, Colonial National Historical Park, and Jamestown Settlement. It also contains industries such as Newport News Shipyard, coal and shipping terminals. Military bases include Fort Monroe, Fort Eustis, Yorktown Coast Guard Center, Langley Air Force Base, Yorktown Naval Weapons Station, and Camp Peary. This development is sometimes in conflict with the seafood industry centered in the lower bay and tributary estuaries.

The Williamsburg map area is entirely within the Coastal Plain province. Map units exposed above sea level consist predominately of estuarine, nearshore marine, and marine unconsolidated sediments of Pliocene and Pleistocene age. There is limited exposure of Miocene marine sediments in the project area. There is a substantial link between the morphology (scarps and flats) and Pleistocene stratigraphy because of world-wide sea-level changes during repeated glacial activity.

Below sea level, early Tertiary and Cretaceous sediments overlie basement rocks. Strata dip as a thickening wedge seaward. Depth to basement ranges from approximately

800 feet in the west part of the map area, 2,100 feet at Newport News to possibly 7,000 feet in the east at Cape Charles. However, the center of the Chesapeake Bay Impact Crater (33My) is located below Cape Charles, with a zone of fractured and faulted basement rocks extending more than 25,000 feet below sea level. The crater has affected basement and overlying Cretaceous through Eocene age sediments out to a diameter of 56 miles (Powars, 2000). The outer rim fault goes through the study area in the Gloucester, Mathews, Newport News, and Hampton quadrangles.

## Purpose and Justification

### *Water Resource Location*

Water supply in the project area comes from surface impoundments and wells. A desalinization plant is under construction for James City County. The city of Newport News has developed several reservoirs in the map area and is in the permit process for an additional reservoir in King William County. The impounded Chickahominy River and the Diascond Reservoir lie within the Walkers 7.5-minute quadrangle (proposed to be mapped in 2006-2007). Newport News and Gloucester have recently begun pumping and desalinizing brackish groundwater to increase their water supply.

### *Economic Product Development*

Sand and gravel resources in the Williamsburg area are currently being lost to housing development. Most of the richest deposits in the coastal plain are found in the fluvial parts of the Pleistocene terraces, adjacent to major rivers (estuaries). Using DMR’s auger drill rig greatly enhances the capability of locating potential aggregate resources. Fossil shell beds have been used as a source of lime (calcium carbonate) and may have a future use as a substrate for reseeding oyster beds. Our mapping has also suggested the presence of heavy mineral deposits in this region.

### *Geologic Hazard Identification*

Coastal flooding, elevated radon concentrations, minor earthquakes, and landslides, sinkholes, shrink-swell clays, and acidic soils are known or potential geologic hazards in the project area.

### *Natural Resource Protection*

Development pressures within the project area are causing changes in land use. During development, open space is converted to industrial, commercial, and residential use. These changes are certain to have both positive and negative effects on the region’s natural resources. In many cases, the geology can play an important role in the nature and extent of these impacts. Detailed geologic maps will provide useful information to land use planners, natural resource caretakers, and environmental consultants who work in the area.

Water contamination is a significant problem in some parts of the project area, which encompasses a lower portion of the Chesapeake Bay. Please refer to this section of the Richmond MSA project proposal for additional information about the York and James River Basins.

***Roads and Infrastructure Development***

Several major highway construction projects are underway or are being planned in the future, including the expansion and realignment of U.S. Highway 460. Detailed geologic maps will provide useful information to the Virginia Department of Transportation, municipal and private utilities, and private and public land developers.

**Strategy for Performing Geologic Mapping**

In order to compile at 1:100,000-scale, mapping will be done at 1:50,000-scale or better and 1:24,000-scale where necessary. At least 25 auger borings will be made in the quadrangle with subsurface information entered into a Microsoft Access database. Geologic contacts and point data will be compiled in a GIS. Rick Berquist will be mapping the quadrangle with assistance from Amy Bondurant.

For 2007-2008, we propose mapping the Walkers 7.5-minute quadrangle (Figure 7). The Walkers quadrangle is within the area of overlap between the Richmond MSA and the Williamsburg 30- x 60-minute quadrangle (Figure 1). It contains a portion of Interstate 64 between Richmond and Williamsburg that is experiencing rapid residential and commercial development.

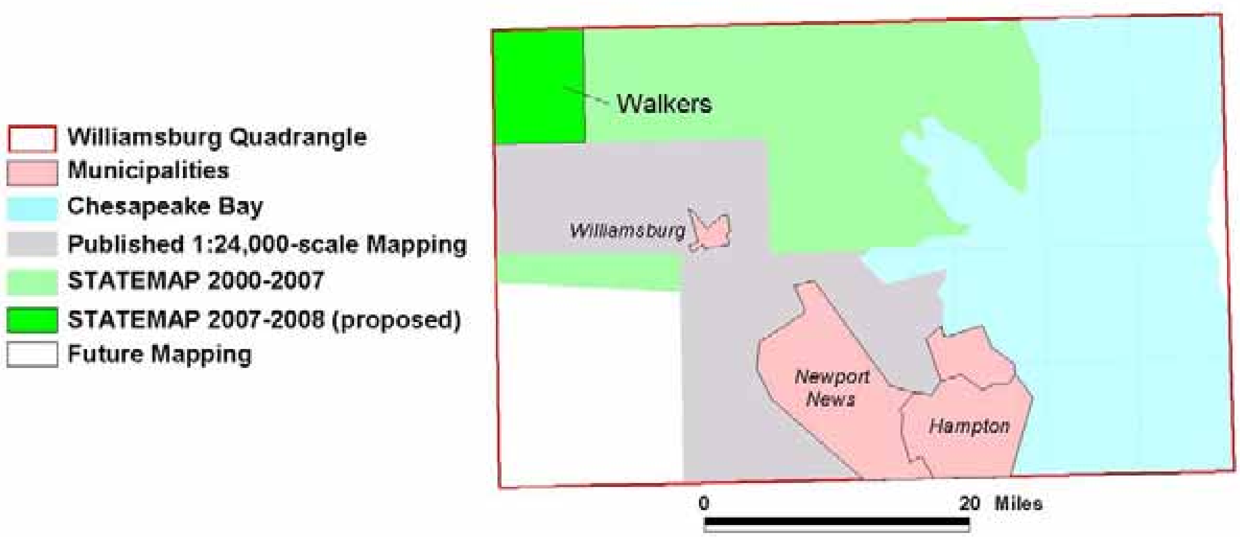



**Figure 7.** 7.5-minute quadrangle proposed for new mapping within the Williamsburg 30- x 60-minute quadrangle project area.

## Preliminary Results and Previous Work

### *Preliminary Results*

The mapping of Gloucester quadrangle and portions of the Surry and Claremont quadrangles, being completed under our current STATEMAP grant, is about 20 percent complete. Over 50 power- and hand-auger borings have been made. Additional borings have been completed in the north-central part of the area where the Sedley, Yorktown, and Eastover formations may have been affected by faulting associated with the outer rim of the Chesapeake Bay Impact Crater. Tertiary sediments disappear below sea level to the east of a north-south line defined by Blackwater Creek and the North River. Work has just begun in the northwest part of Gloucester quadrangle.

### *Previous Work*

All previously published maps and STATEMAP deliverables have been compiled at the original map scale (1:24,000 and 1:50,000) with a plotted map at 1:100,000-scale (Figure 7).

## Deliverable Maps

The deliverable for this project will be a geologic map and cross-section of the Walkers quadrangle.

## SUMMARY OF PREVIOUS STATEMAP PRODUCTVITY

DMR has a 100 percent on-time record for STATEMAP deliverables since the program began. Over the past few years we have had a growing and productive STATEMAP program.

Our 2006 STATEMAP project ($209,354 federal funding) consists of geologic mapping of all or portions of nine quadrangles: Atkins, Augusta Springs, Bent Mountain, Chesterfield, Claremont, Drewry's Bluff, Gloucester, Saltville, and Surry; and digital compilation of all or portions of ten quadrangles: Bon Air, Boones Mill, Brownsburg, Garden City, Hardy, Lexington, Radford North, Redwood, Seven Pines, and Staffordsville.

Our 2005 STATEMAP project ($227,186 federal funding) consists of geologic mapping of all or a portion of seven quadrangles: Gloucester, Lexington, Marion, Redwood, Saltville, Vesuvius, and Ware Neck; a surficial geologic map of the northern half of the Grottoes quadrangle; and a geologic and digital compilation of all or portions of five quadrangles: Arnold Valley, Bon Air, Buchanan, Natural Bridge, Richmond and Seven Pines.

Our 2004 STATEMAP project ($171,151 federal funding) consists of geologic mapping of the Boones Mill, Garden City, Hamburg, and Hardy quadrangles; a surficial geologic map of the northern half of the Grottoes quadrangle; and a geologic and digital compilation of four 1:24,000 quadrangles: Crimora, Parnassus, Waynesboro East, and Waynesboro West.

Our 2003 STATEMAP project ($95,955 federal funding) consisted of a geologic and digital compilation of eleven 1:24,000 quadrangles: Bridgewater, Broadway, Fort Defiance, Greenville, Grottoes, Harrisonburg, Mt. Sidney, New Market, Staunton, Stuarts Draft, and Tenth Legion.

Our 2002 STATEMAP project ($31,000 federal funding) consisted of mapping portions of five 1:24,000 quadrangles: Hayters Gap, Glade Spring, Chilhowie, Damascus, and the Virginia portion of Laurel Bloomery.

Our 2001 STATEMAP project ($14,899, federal funding) consisted of mapping three 1:24,000 quadrangles in the Virginia coastal plain (Mathews, Achilles, and New Point Comfort).

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